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Research Article

Global Research Trend Analysis of *Osmanthus fragrans* Based on Bibliometrix

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Osmanthus fragrans is the ornamental and practical excellent garden tree featured with greening, beautification, and fragrance in one, and has been domesticated in China for 2500 years. Besides, an increasing number of papers on *O. fragrans* have been published so far, but these contributions have not been analyzed comprehensively. Considering that, in this research, a bibliometric methodology is adopted on documents related to *O. fragrans* obtained from the WoS database. The study demonstrated the main countries and institutions in terms of this field. Among them, the Chinese research on *O. fragrans* is in a leading position in the world. Regarding the specialization, the institution ranking is led by the Nanjing Forestry University, Henan University, and Zhejiang University. Apart from that, analysis on the keywords also highlighted the lines of research associated with plant functionality (e.g., antioxidant, antifungal activity, and anti-inflammatory activities), natural products (e.g., carotenoids, aroma, flavonoids, essential oils, phenylethanoid glycosides, and salidroside), and molecular biology (e.g., genetic diversity, transcription factors, and phylogeny). The results from this study also revealed that there is a lack of research on the production mechanism of floral fragrance and the flower color regulation mechanism in *O. fragrans*. Moreover, the aroma and flower color are gradually developing into the main areas of research on *O. fragrans*. It is also expected that future research in this field will focus on biochemistry and biomolecules.

1. Introduction

Osmanthus fragrans (*O. fragrans*) is an evergreen tree or shrub that belongs to the family Oleaceae. The shrub is a well-known ornamental plant and is native to the Sino-Himalayan region [1]. Besides, *O. fragrans* is one of the earliest ornamental plants in the world, and its cultivation history is more than 2500 years [2, 3]. In addition, it originated from China before being introduced into Japan in the ancient times. Thereafter, it was brought into Britain from China or Japan in 1771, followed by France, the Netherlands, and other European countries. Finally, the plant was introduced into South Asia, Southeast Asia, and other places [4]. In 1784, the Swedish botanist C.P. Thunberg published the first scientific name for *O. fragrans*, where it was called Olea fragrans Thunb. Given that there was no Osmanthus at that time, O. *fragrans* was classified as Olea. About 6 years later in 1790, the Portuguese botanist J. Loureiro made the first record of Osmanthus by taking *O. fragrans* as a type species in "Flora Cochinchinensis," which was the only species recorded at the time. In 1958, the British botanist, P.S. Green published the classic work, "*A Monographic Revision of Osmanthus in Asia and America*" that systematically highlighted the morphology and classification of Osmanthus [5]. In December 2004, Professor Xiang Qibai, from Nanjing Forestry University, successfully declared the "International Registration Authority of *O. fragrans* Varieties," which promoted research on Osmanthus, especially *O. fragrans* [6]. Currently, *O. fragrans* is classified into four cultivar groups, namely, Semperflorens, Odoratus, Thunbergii, and Aurantiacus. Notably, the Odoratus group is mainly creamy yellow to light yellow, and the Thunbergii group is majorly medium yellow to deep yellow, while the Aurantiacus group is mainly orange to pinkish-orange. Additionally, the cultivar groups are composed of several distinct colors, with significant differences within different cultivar groups [7, 8]. Furthermore, there are currently more than 170 registered cultivars of *O. fragrans* in China.

O. fragrans is a well-known spice that is rich in aromatic components, most of which possess antioxidant properties (e.g., terpenes). Therefore, it has been widely used to make tea, food, and spices since the ancient times [9, 10]. Additionally, fresh *O. fragrans* can be soaked in salt or sugar, and then sealed and stored in a jar to make pickled (sugared) *O. fragrans*, which can in turn be used in various desserts or as a type of seasoning. Moreover, osmanthus wine, made of glutinous rice and *O. fragrans* consists of a variety of amino acids which are required by the human body. The wine is also highly valued for its sweet taste and delicious nature. Furthermore, *O. fragrans* can be used to make healthy food, including Osmanthus porridge, cake, and pastry [11]. Furthermore, advances in technology have also made it possible to extract the essential oil in *O. fragrans*, which is widely applied in food, skincare products, and cosmetics [12, 13]. Thus, *O. fragrans* has great potential and huge prospects in the modern flavor industry.

In addition, the flower of *O. fragrans* is the most crucial ornamental part of the plant. As such, extensive research has been conducted on the flower color, fragrance, and active ingredients. For instance, as early as 1967, K.S. Siside from Japan studied the components of Japanese and Chinese *O. fragrans* extracts [14]. In 1989, Ding et al. used GCMS to conduct headspace analysis of three *O. fragrans* cultivars and detected a total of 55 chemical components [15]. Moreover, in the early 21st century, Fu et al. compared the floral release of four *O. fragrans* cultivars under different temperatures [16]. Their findings showed that alcohols and ketones were the two main compounds that responded to changes in temperature, suggesting that temperature affected the release of fragrance in flowers to a great extent. Furthermore, studies on the color of *O. fragrans* mainly focus on carotenoids. It was reported that differences in the composition and concentration of pigments in *O. fragrans* cultivars were caused by the differential expression of downstream genes in the carotenoid synthesis pathway and genes in the carotenoid degradation pathway [17–19]. Therefore, these studies provide useful insights that may be utilized to explore the practical applications of the color and fragrance components of *O. fragrans* flower.

The *O. fragrans* extract also contains over 100 active ingredients, including flavonoids, phenols, terpenoids, lignans, and phenylpropanoids [12, 20, 21]. In addition, the extract is characterized with various pharmacological activities, such as antioxidation, anti-inflammation, neuroprotection, and antiaging [22–24]. Notably, starting in 2007, research on the neuroprotective and free radical scavenging effects of *O. fragrans* was conducted [25]. The study assessed the free radical scavenging effect of ethanol extracts from *O. fragrans*. Besides, a separate study conducted in 2013 also showed that ethanol extracts from the flowers of *O. fragrans* could alleviate oxidative stress and allergic airway inflammation in animal models [26]. Beyond that, a study conducted in 2015 further demonstrated that the ethanol extract from *O. fragrans* impairs the inflammatory effect stimulated by *P. gingivalis*-LPS through the antioxidation signaling pathway, mediated by the nuclear factor erythroid 2-related factor [27]. Moreover, in a previous study on the antiaging effect of the *O. fragrans* extract, an aging ICR mouse model was established through long-term application of D-galactose for 8 weeks and subsequent feeding with the *O. fragrans* extract. The findings showed that the *O. fragrans* extract could inhibit the neuro-aging induced by D-galactose [28].

Over the past two decades, technological advances in molecular biology have facilitated great progress in functional research on *O. fragrans*. Obviously, a number of genes related to flower color and aroma formation in *O. fragrans*, including Of4CL, OfCHS, OfGES, OfZ-ISO1, OfPAL, OfCHI, OfC4H, and OfCRTISO have been cloned successively [9, 10, 29, 30]. In 2014, the transcriptome of *O. fragrans* was sequenced through the Illumina HighSeqTM2000 sequencing platform. The results of functional annotation revealed 197 and 237 candidate genes involved in the formation of spices and pigment biosynthesis, respectively [2]. Moreover, whole genome sequencing of *O. fragrans* is currently underway, which will enable research on flower color, genes responsible for the formation of fragrance, those involved in blooming, and genes associated with resistance to stress [17, 31, 32].

There are also some factors hindering the progress of *O. fragrans* related research. First of all, *O. fragrans* has a relatively small distribution and recognition in the world, and its distribution in China is only limited to the south of the Yellow River. Secondly, the flowering period of *O. fragrans* is very short, which is a great limitation for the industrialization of *O. fragrans*. In the end, it is technically difficult to extract and preserve the fragrant substances of *O. fragrans*.

Bibliometrics is a discipline for quantitative analysis of literature. It can objectively and multidimensionally analyze the whole layout of a particular field. Besides, in the discipline, not only can the research centers and advantageous teams be quantitatively organized, but also the research hotspots can be pointed out [33–35]. Several papers on *O. fragrans* have been published so far, but their contributions have not been analyzed comprehensively. Therefore, based on a bibliometric analysis of globally published literature on *O. fragrans*, this paper tends to understand the current status of the field and identify gaps that require further research.

2. Materials and Methods

Data were obtained from SSCI, SCIE, and the Web of Science (WoS), while studies were identified based on the search term, "*Osmanthus fragrans*∗." Then, the identified articles were scrutinized to select those that met the study objectives. In addition, here, articles published between 1975 and 2020 were searched for. Finally, 209 articles on *O. fragrans* were obtained. The selection of the samples was carried out in March 2021.

Based on the above datasets, the study used the Bibliometrix and ArcGIS 10.6 software to visualize the results. Bibliometrix is a tool based on the R language that is used for full-process document analysis and network visualization [36, 37]. In addition, the Biblioshiny software was employed to visualize the distribution density of countries, cooperation between authors and institutions, keywords, and research hotspots [38, 39]. It is also noteworthy that in the conceptual structure function in Bibliometrix, multivariate correspondence analysis (MCA) is performed to draw the conceptual structure of the research field, and the K-means clustering method is adopted to cluster documents [40].

3. Results and Discussion

3.1. Trends in Scientific Output. Figure 1 displays the trends in the yearly number of publications for studies on *O. fragrans* in agriculture. Actually, 209 articles on *O. fragrans* were published between 1975 and 2020. Beyond that, two different stages of development were involved. The first stage is from 1975 to 2008. The research on *O. fragrans* existed in an intermittent state. The second stage is from 2009 to 2020. Research on the subject exploded, and reached its peak in 2018 with 29 articles being published. This is mainly for two reasons. First, after the approval of the registration right of *O. fragrans* varieties in China, relevant research was promoted [6]. Second, due to China's rich variety resources, China's scientific research funding increased from more than 57 billion USD in 2008 to more than 270 billion USD in 2018. A combination of multiple factors has promoted scientific publications from investigations on *O. fragrans* [41].

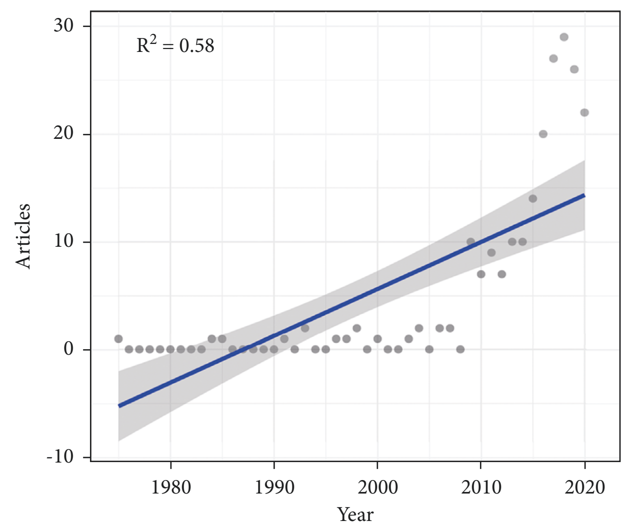

Figure 1: Trend of the number of publications per year on *O. fragrans* from the years 1975–2020.

Table 1: The 10 most productive countries of research in *O. fragrans*.

Country	Articles	Freq	SCP	MCP
China	165	0.793	149	16
Japan	21	0.101	17	4
Korea	8	0.038	8	0
USA	5	0.024	4	1
Singapore	2	0.01	1	1
Brazil	1	0.005	0	1
Czech Republic	1	0.005	1	0
Germany	1	0.005	0	1
Greece	1	0.005	0	1
India	1	0.005	1	0

SCP: single country publications; MCP: multiple country publications.

3.2. Publication Distribution by Countries and Institutions. Overall, majority of publications were from countries that allocate a large number of funds to research and development [42–44]. The interest in *O. fragrans* research is extremely uneven among different countries. The results show that the top five countries in terms of published articles are China, Japan, Korea, the United States, and Singapore (Table 1). Among them, more than 70% of the total publications come from China that has the most international collaboration articles. Judging from the number of papers published in countries and regions, Chinese research on *O. fragrans* possesses the leading position in the world and has great influence.

In Table 2, the 10 most important institutions in this field are represented. The Nanjing Forestry University is leading the ranking. As the highest academic institution in China's forestry disciplines, it is a multidisciplinary university with forestry as its characteristics and advantages in resources, ecology, and environment disciplines [45]. The second position is held by the Henan University. As a major agricultural province in China, Henan province accounts for nearly one-tenth of China's total grain output. Hence, agronomy is featured with a long tradition and high competence [46, 47]. The next eight positions are held by only one institution in South Korea and the others are Chinese institutions.

Table 2: The 10 most productive organizations of research in *O. fragrans*.

Affiliations	Articles
Nanjing forestry Univ	89
Henan Univ	35
Zhejiang Univ	29
Zhejiang Agr and forestry Univ	28
Huazhong Agr Univ	17
Kyung Hee Univ	15
Guangxi normal Univ	13
Jiangsu Univ	13
Chinese Acad sci	12
Jiangnan Univ	12

From Figure 2, the cooperation on *O. fragrans* research between China and the United States is the most, with a total of 8 times. Other than that, China and Japan have

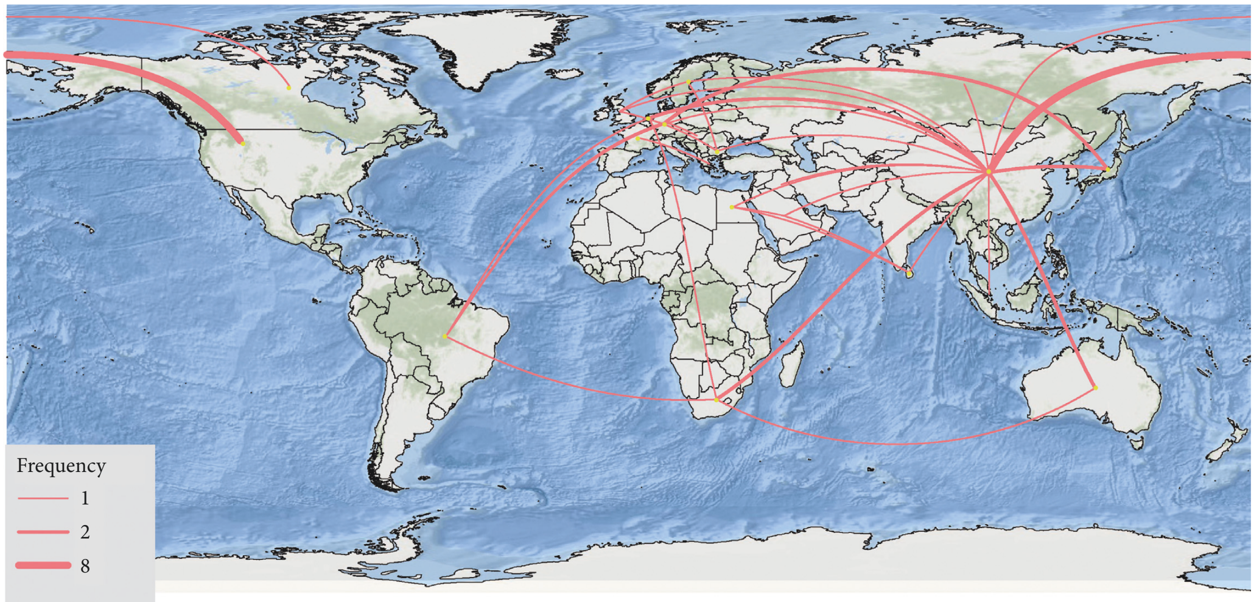

Figure 2: Country collaboration world map of research in *O. fragrans*.

Table 3: The 10 most productive journals of research in *O. fragrans*.

Source	Articles	H-index	G-index
Molecules	7	6	7
Food chemistry	5	4	5
Frontiers in plant science	5	4	5
Scientific reports	5	3	5
Environmental science and pollution research	4	2	2
International journal of agriculture and biology	4	2	2
Journal of agricultural and food chemistry	4	4	4
Forests	3	2	3
Genes	3	1	3
Horticulture research	3	2	3

cooperated twice. Indeed, there is often a lack of regional and international cooperation to deal with the challenges of *O. fragrans* scientific research. For this reason, it is essential to enhance international collaboration and research.

3.3. Most Relevant Journals. Since research on *O. fragrans* is diverse in terms of the disciplines involved, many journals with specific focus on this topic have been created [48, 49]. Some journals lay emphasis on biology, plants, and molecules, while others are centered on agriculture, horticulture, natural products, etc. [50, 51]. Table 3 shows the most prolific journals in terms of *O. fragrans* research during the period of 1975 to 2020. The *Molecules* journal has the highest number of publications with a five-year impact factor (IF) of 3.589, a total of 7 articles, an H-index of 6 and a G-index of 7. The journal with the second number of articles published is *Food Chemistry* with a five-year IF of 5.046, a total of 5 articles, an H-index of 4, and a G-index of 5, followed by *Fronters in Plant Science* and *Scientific Reports*. The academic influence of these 4 journals in this field is dominant.

3.4. Main Scientific Articles. In Table 4, the highlights obtained by Bibliometrix or the most cited documents are Huang et al. [52], Li et al. [53], Wang et al. [54], and Baldermann et al. [4], in terms of normalized total citations. The normalization adjusts for the fact that earlier research may receive more citations than more recent studies. Additionally, Li et al. [53] and Chen et al. [55] are the document with the highest normalized citations. Moreover, it is worth mentioning that the work of Li et al. [53] describes *Osmanthus fragrans* found to have the highest antioxidant capacity in 51 edible and wild flowers from China.

Table 4: The 10 main scientific articles of research in *O. fragrans*.

Paper	Total citations	TC per year	Normalized TC
Huang et al. [52]	132	9.4	3.8
Li et al. [53]	121	13.4	5.3
Wang et al. [54]	92	5.4	1.3
Baldermann et al. [4]	83	6.4	3.6
Chen et al. [55]	77	9.6	5.2
Wang et al. [11]	68	4.8	1.9
Ômura et al. [56]	60	2.6	1.1
Wu et al. [57]	58	4.1	1.6
Watanabe et al. [58]	53	1.7	1.7
Lee et al. [25]	49	3.1	1.8

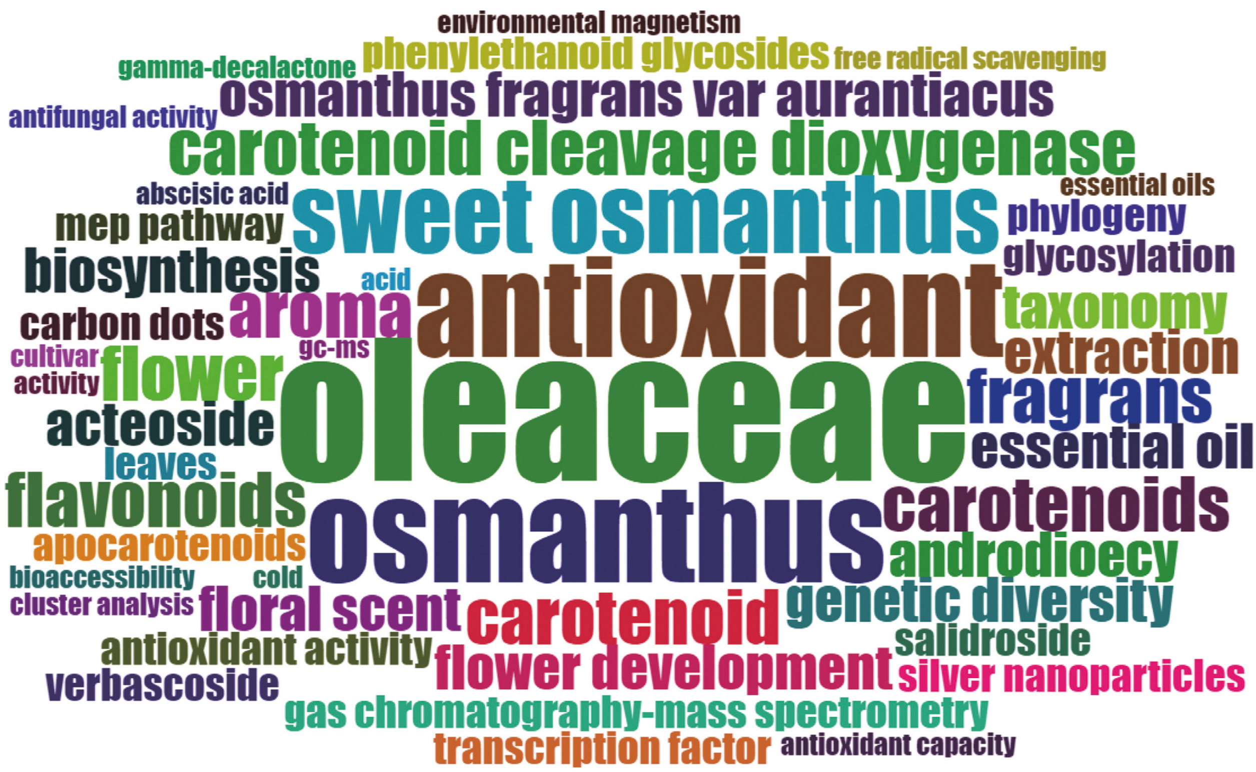

Figure 3: Word cloud based on the main keywords related to *O. fragrans*.

3.5. Analysis of Keywords. The main research topics in a given manuscript are summarized by keywords defined in it. Therefore, the evaluation of keywords in scientific literature can determine research trends in a particular field [59].

Figure 3 shows the word cloud composed of 50 keywords displayed by the WOS database for articles related to *O. fragrans*. Obviously, "Oleaceae" and "Osmanthus" are the most frequent keywords, which are the taxonomic nomenclature of *O. fragrans* [30]. The second most employed *O. fragrans*-related keyword is "antioxidant." *O. fragrans* has been proven to have the ability to scavenge DPPH, hydroxyl, and $ABTS^+$ free radicals [60, 61]. The keywords "aroma" and "carotenoid" are quite abundant in documents related to *O. fragrans* whose extract is widely used in the chemical, food, health food, and pharmaceutical industries. The research on the "aroma" is of great significance to the development of specific products and the development of social economy [62, 63]. In higher plants, "carotenoid" functions importantly as the colorant of flowers and fruits [64, 65]. Furthermore, there are four *O. fragrans* cultivar groups, which exhibit significant intergroup differences in flower coloration. Elucidating the mechanism of the color variation of *O. fragrans* from the perspective of carotenoids can enrich the basic theoretical knowledge of *O. fragrans* and provide theoretical basis for the improvement, development, and cultivation of new varieties of *O. fragrans* [18, 66].

MCA is aimed at multiple categorical variables, trying to find the correlation between the levels of these variables. The results are interpreted based on the relative positions of the points and their distribution along the dimensions. The more similar the words are in their distribution, the closer they are represented on the map [67]. Apart from that, in the analysis of the keywords (Figure 4), two differentiated groups are observed. In the blue cluster, these keywords are mainly related to the methodology of *O. fragrans* extraction. Many keywords that are difficult to classify, including plant functionality (e.g., antioxidant, antifungal, and anti-inflammatory activities), natural products (e.g., carotenoid, aroma, flavonoids, essential oil, phenylethanoid glycosides, and salidroside), and molecular biology (e.g., genetic diversity, transcription factors, and phylogeny) are collected in the red cluster. With the progress of biochemistry and molecular biology, the studies on the physiological and biochemical mechanisms in *O. fragrans* development evolve rapidly.

The basic themes of research on *O. fragrans* were carotenoid cleavage dioxygenase and carotenoid (Figure 5), whereas other important basic topics were sweet fragrans and aromas. The Oleaceae, androdioecy, and genetic diversity have been on the border between basic and emerging themes. The most important emerging topics were the flavonoids in leaves and flowers. Interestingly, the studies analyzing carbon dots and molecular imprinting in *O. fragrans* were rather peripheral ones.

According to the thematic evolution of Keywords (Figure 6), the research topics on *O. fragrans* began to diversify from 2013. "Extraction" diversifies towards the "aroma" and "essential oil". At the same time, "osmanthus" diversifies towards the "flower" and "carotenoid cleavage dioxygenase." Moreover, no breakthrough has been made in the extraction and preservation technology of *O. fragrans*.

Early research on *O. fragrans* focused on natural product extraction and variety selection [68–71]. With the continuous development of research technology, the depth of

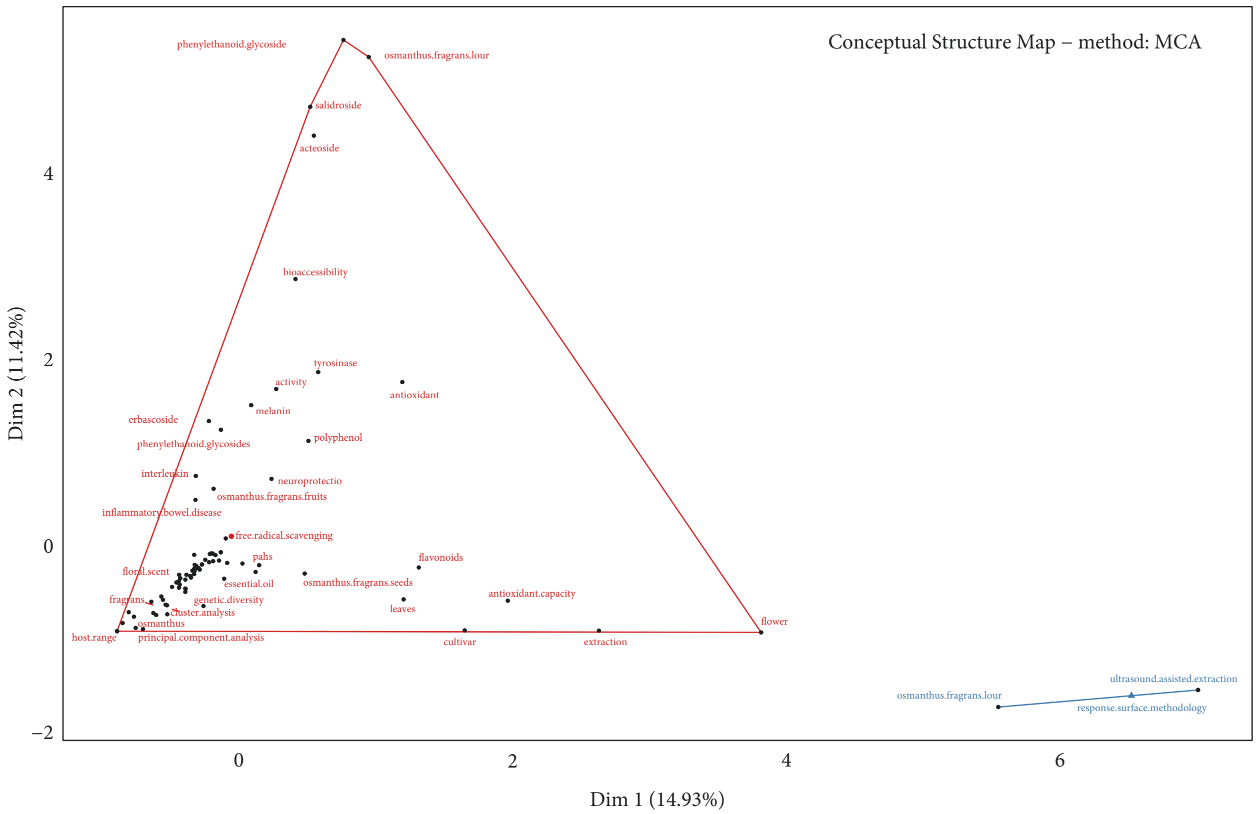

Figure 4: Conceptual structure map by author keywords of research in *O. fragrans*.

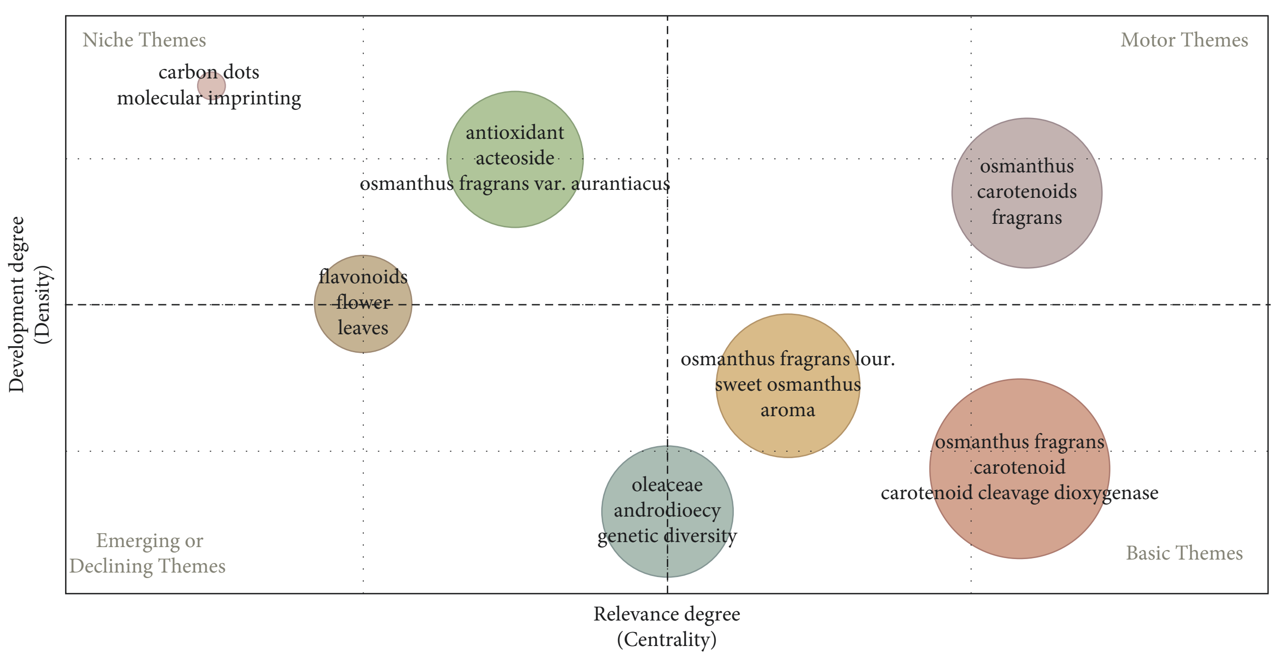

Figure 5: Strategic map by author keywords of research in *O. fragrans*.

research is also increasing. Two hotspots gradually appeared in the research of *O. fragrans*: one is the aroma and the other is flower color. Here, it should be noted that *O. fragrans* is famous for its unique fragrance. Some studies have revealed the regulatory mechanism of the floral fragrance by regulating the synthesis of β-ionone by transcripts [62, 72]. Researchers also pay attention to colors. They have clarified the relationship between CCD4 genes and carotenoid in flowers and explored the regulation mechanism of *O. fragrans* flower color [17, 29, 73]. In the last decade, after

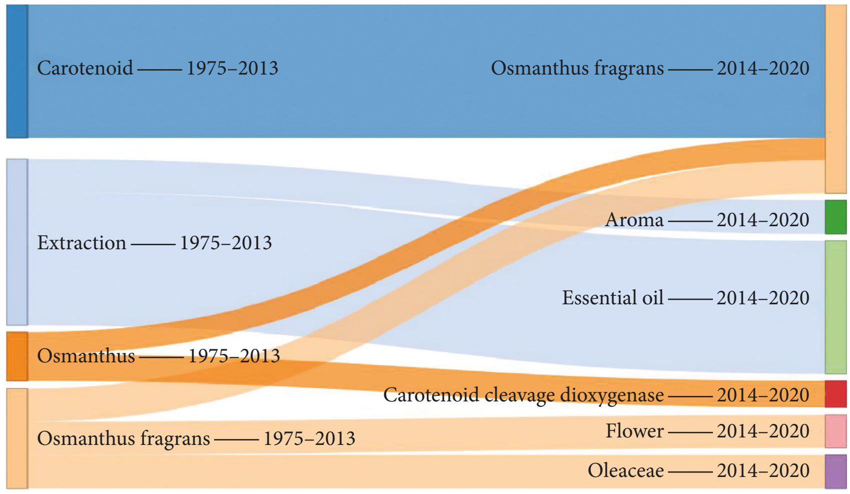

Figure 6: Topic evolution by author keywords of research in *O. fragrans*.

the successful application for the international registration right of *O. fragrans* varieties in China, researchers have continuously probed into the value of *O. fragrans* through the integration of various disciplines [74–76]. However, the genetic transformation system of *O. fragrans* has not yet been successful, which affects the transgenic technology and gene editing technology that cannot be used in *O. fragrans*.

4. Conclusions

The bibliometric assessment of scientific documents related to *O. fragrans* enabled the present analysis to explore the past and current trends in research on *O. fragrans*.

Notably, over the past 45 years, there has been growth in the number of publications associated with *O. fragrans* in agriculture, which has been fueled by the approval of registering *O. fragrans* varieties in China and the large investment in scientific research.

In addition, China is among the leading countries in research on *O. fragrans*, with great global influence. The analysis showed that the three leading countries in this field (China, Japan, and Korea) possess 90% of all the publications, indicating the importance of these countries in research on *O. fragrans*. However, there is often a shortage of regional and international cooperation to address the challenges associated with research on *O. fragrans*. Therefore, in the future, it is essential to enhance international collaboration and research. The results also demonstrated that several public and private organizations are committed to conducting research on *O. fragrans*. Particularly, the institutions from China (Nanjing Forestry University, Henan University, and Zhejiang University) were shown to be the most dedicated, followed closely by the Kyung Hee University (Korea).

For the purpose of studying the most relevant journals, in this bibliometric research, both the quantitative (volume of publications) and qualitative indicators (number of citations) were analyzed. Therefore, based on the number of publications, H-index and G-index, *Molecules* was considered to be the most influential journal, followed by *Food Chemistry*, *Fronters in Plant Science,* and *Scientific Reports*.

Analysis of the keywords also highlighted the lines of research related to plant functionality (e.g., antioxidant, antifungal, and anti-inflammatory activities), natural products (e.g., carotenoids, aroma, flavonoids, essential oils, phenylethanoid glycosides, and salidroside), and molecular biology (e.g., genetic diversity, transcription factors, and phylogeny), but the genetic transformation system of *O. fragrans* has not yet been successful, which affects the transgenic technology and gene editing technology that cannot be used in *O. fragrans*. The results from this study also revealed that there is a lack of research on the production mechanism of floral fragrance and the flower color regulation mechanism in *O. fragrans*. Moreover, the aroma and flower color are gradually developing into the main areas of research on *O. fragrans*. It is also expected that future research in this field will focus on biochemistry and biomolecules.

The main limitation of this research is that it was restricted to the WoS and only articles were analyzed. Therefore, it would be interesting to consider a broader line of research that includes other databases such as Scopus or Google Scholar as well as other types of publications such as books or conference proceedings. Another limitation is that not all articles of research on *O. fragrans* up to now are covered, and only those between 1975 and 2020 are considered.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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